Cerebellum

■ PARTS OF CEREBELLUM

Cerebellum consists of a narrow, worm-like central body called **vermis** and two lateral lobes, the right and left **cerebellar hemispheres** (Fig. 150.1).

■ VERMIS

Vermis of cerebellum is formed by nine parts. Part of vermis on the upper surface of cerebellum is known as **superior vermis** and the part on lower surface of cerebellum is called **inferior vermis.**

Parts of superior vermis and inferior vermis are listed in Table 150.1.

Nodulus is continued on either side as an elongated and somewhat lobulated structure called flocculus. Nodulus and **flocculi** are together called **flocculonodular lobe**. On either side of pyramid, there is another extension named paraflocculus.

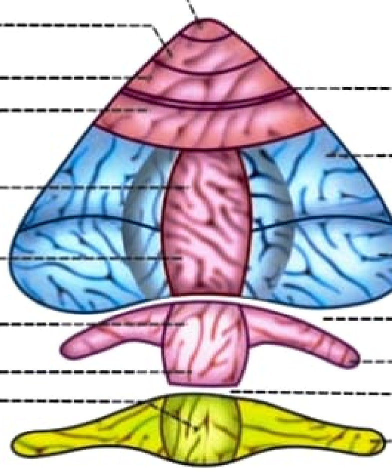

FIGURE 150.1: Parts and functional divisions of cerebellum

TABLE 150.1: Parts of superior and inferior vermis

Superior vermis	Inferior vermis
1. Lingula	6. Tuber
2. Central lobe	7. Pyramid
3. Culmen	8. Uvula
4. Lobulus simplex	9. Nodulus
5. Declive	

Fissures Present Over the Surface of Vermis

1. Primary fissure between culmen and lobulus simplex
2. Prepyramidal fissure between tuber and pyramid
3. Posterolateral fissure between uvula and nodulus.

CEREBELLAR HEMISPHERES

Cerebellar hemispheres are the extended portions on either side of vermis.

Each hemisphere has two portions:

1. **Lobulus ansiformis** or **ansiform lobe,** which is the larger portion of cerebellar hemisphere
2. **Lobulus paramedianus** or **paramedian lobe,** which is the smaller portion of cerebellar hemisphere.

DIVISIONS OF CEREBELLUM

Division of cerebellum into different major parts is done by three methods:

A. Anatomical divisions
B. Phylogenetic divisions
C. Physiological or functional divisions.

ANATOMICAL DIVISIONS

On structural basis, the whole cerebellum is divided into three portions:

1. Anterior lobe
2. Posterior lobe
3. Flocculonodular lobe.

1. Anterior Lobe

Anterior lobe includes lingula, central lobe and culmen. It is separated from posterior lobe by primary fissure.

2. Posterior Lobe

Posterior lobe consists of lobulus simplex, declive, tuber, pyramid, uvula, paraflocculi and the two portions of hemispheres, viz. ansiform lobe and paramedian lobe.

3. Flocculonodular Lobe

Flocculonodular lobe includes nodulus and the lateral extension on either side called flocculus. It is separated from rest of the cerebellum by posterolateral fissure.

PHYLOGENETIC DIVISIONS

Depending upon phylogeny, the cerebellum is divided into two divisions:

1. Paleocerebellum
2. Neocerebellum.

1. *Paleocerebellum*

Paleocerebellum is the phylogenetically oldest part of cerebellum. It includes two divisions:

i. **Archicerebellum,** which includes flocculonodular lobe
ii. **Paleocerebellum proper,** which includes lingula, central lobe, culmen, lobulus simplex, pyramid, uvula and paraflocculi.

2. *Neocerebellum*

Neocerebellum is the phylogenetically newer portion of cerebellum. It includes declive, tuber and the two portions of cerebellar hemispheres, viz. lobulus ansiformis and lobulus paramedianus.

■ PHYSIOLOGICAL OR FUNCTIONAL DIVISIONS

Based on functions, the cerebellum is divided into three divisions:

1. Vestibulocerebellum
2. Spinocerebellum
3. Corticocerebellum.

1. *Vestibulocerebellum*

Vestibulocerebellum includes flocculonodular lobe that forms the archicerebellum.

2. *Spinocerebellum*

Spinocerebellum includes lingula, central lobe, culmen, lobulus simplex, declive, tuber, pyramid, uvula and paraflocculi and medial portions of lobulus ansiformis and lobulus paramedianus.

3. *Corticocerebellum*

Corticocerebellum includes lateral portions of lobulus ansiformis and lobulus paramedianus.

■ FUNCTIONAL ANATOMY OF CEREBELLUM

Cerebellum is made up of outer gray matter or **cerebellar cortex** and an inner **white matter.** White matter is formed by afferent and efferent nerve fibers of cerebellum. Gray masses called **cerebellar nuclei** are located within the white matter.

■ GRAY MATTER

Gray matter or cerebellar cortex is made up of structures arranged in three layers (Fig. 150.2). Each layer of gray matter is uniform in structure and thickness, throughout the cerebellum.

Layers of gray matter:

1. Outer molecular or plexiform layer
2. Intermediate Purkinje layer
3. Inner granular layer.

1. *Molecular or Plexiform Layer*

Molecular or plexiform layer is the outermost layer of cortex having the cells arranged in two strata. Superficial stratum contains few star-shaped cells known as **stellate cells.** Deep stratum contains **basket cells.** In addition to stellate and basket cells, the molecular layer contains the following structures:

i. **Parallel fibers,** which are the axons of granule cells, present in granular layer
ii. Terminal portions of **climbing fibers** (afferents from medulla)
iii. Dendrites of **Purkinje cells** and **Golgi cells.**

Cell junctions in molecular layer

Molecular layer contains the following cellular junctions:

i. Dendrites of stellate cells and basket cells synapse with parallel fibers, which are the axons of granule cells
ii. Axons of stellate cells end on the dendrites of Purkinje cells. However, the axon of basket cell descends down into the Purkinje layer and forms the transverse fiber, that ends on the soma of Purkinje cells.
iii. Dendrites of Purkinje cells synapse with climbing fibers and parallel fibers
iv. Dendrites of Golgi cells situated in inner granular layer enter the molecular layer and end on parallel fibers.

2. *Purkinje Layer*

Purkinje layer is situated in between outer molecular layer and inner granular layer. It is the thinnest layer, having a single layer of flask-shaped **Purkinje cells.** Purkinje cells are the largest neurons in the body. Dendrites of these cells ascend through the entire thickness of molecular layer and arborize there. These dendrites terminate either on climbing fibers or the parallel fibers. Axons of the basket cells form the transverse fibers, which descend down and end on the soma of Purkinje cells. Axons of Purkinje cells descend into the white matter and terminate on the cerebellar nuclei and vestibular nuclei via cerebellovestibular tract.

Purkinje cells are termed as **'final common path' of cerebellar cortex.** It is because the impulses from

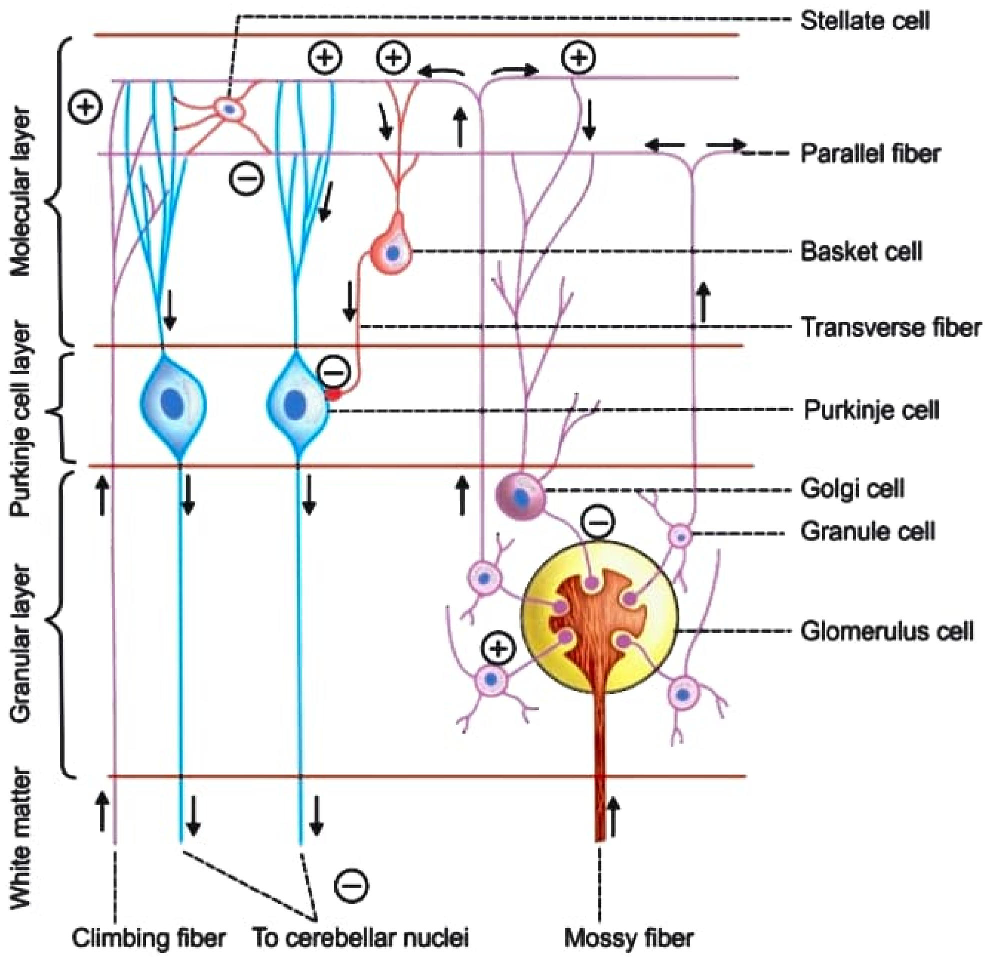

FIGURE 150.2: Structure of cerebellar cortex. (+) = Excitation, (–) = Inhibition.

different parts of cerebellar cortex are transmitted to other parts of brain only through Purkinje cells.

3. Granular Layer

Granular layer is the innermost layer of cerebellar gray matter and it is in between Purkinje layer and the cerebellar white matter. It is formed by interneurons called **granule cells** and **Golgi cells.** Total number of interneurons in this layer is about half the number of all neurons in the whole nervous system.

Axon of granule cell ascends into molecular layer and forms the parallel fiber, which synapses with dendrites of Purkinje cells, stellate cells, basket cells and Golgi cells. Dendrites of granule cells and the axon and few dendrites of a Golgi cell synapse with **Mossy fiber.** The synaptic area of these cells is called **glomerulus** and it is encapsulated by the processes of **glial cells.**

Afferent Fibers to Cerebellar Cortex

Cerebellar cortex receives afferent signals from other parts of brain through two types of nerve fibers:

1. Climbing fibers
2. Mossy fibers.

1. *Climbing fibers*

Climbing fibers arise from the neurons of inferior olivary nucleus, situated in medulla and reach the cerebellum via **olivocerebellar tract. Inferior olivary nucleus** relays the output signals from motor areas of cerebral cortex and the proprioceptive signals from different parts of the body to the cerebellar cortex via climbing fibers. Proprioceptive impulses from different parts of the body reach the inferior olivary nucleus through spinal cord and vestibular system.

After reaching the cerebellum, the climbing fibers ascend into molecular layer and terminate on the dendrites of Purkinje cells. While passing through cerebellum, climbing fibers of olivocerebellar tract send collaterals to cerebellar nuclei. So, impulses from cerebral cortex and proprioceptors of the body are conveyed not only to cerebellar cortex, but also to the cerebellar nuclei through the climbing fibers. Each climbing fiber innervates one single Purkinje cell.

2. *Mossy fibers*

Unlike climbing fibers, the mossy fibers have many sources of origin, namely motor areas of cerebral cortex, pons, medulla and spinal cord. Fibers arising from all these areas send collaterals to cerebellar nuclei before reaching the cerebellar cortex. So, like climbing fibers, mossy fibers also convey afferent impulses to both cerebellar nuclei and cerebellar cortex. Some of the mossy fibers arise from cerebellar nuclei.

Mossy fibers reach the granular layer of cerebellar cortex and divide into many terminals. Each terminal enters a specialized structure called glomerulus and ends in a large expanded structure that forms the central portion of the glomerulus. Dendrites of granule cells and axon and dendrites of Golgi cells synapse on the mossy fiber giving a thick bushy appearance. The word **'mossy'** refers to the appearance of a plant called **moss,** which grows into dense clumps and hence, these fibers are called mossy fibers.

Neuronal Activity in Cerebellar Cortex and Nuclei

Functions of cerebellum are executed mainly by the impulses discharged from cerebellar nuclei. However, cerebellar cortex controls the discharge from nuclei constantly via the fibers of Purkinje cells. It is done in accordance with the signals received by cerebellar cortex from different parts of the brain and body via climbing and mossy fibers.

Entire process involves a series of neuronal activity:

1. Climbing fibers excite the Purkinje cells directly and cerebellar nuclei via collaterals, by releasing **aspartate.** Excitatory effect of climbing fiber on Purkinje cell is very strong because each climbing fiber ends on a single Purkinje cell (Table 150.2).
2. Mossy fibers excite the Purkinje cells indirectly. In the glomeruli, mossy fibers release glutamate and excite the granule cells and Golgi cells. Collaterals of mossy fibers activate the cerebellar nuclei also by **glutamate.**
3. Granule cells, which are activated by mossy fibers in turn, excite the Purkinje cells, stellate cells and the basket cells through the parallel fibers.

   Neurotransmitter utilized by granule cells is **glutamate** or **aspartate.** Granule cells are the only excitatory cells in cerebellar cortex, while all other cells are inhibitory in function. Each mossy fiber innervates many Purkinje cells indirectly via granule cells. So, the excitatory effect of mossy fibers on Purkinje cells is weak.
4. Stellate cells and basket cells, which are activated by granule cells, inhibit the Purkinje cells by releasing GABA. This type of inhibition is called feed forward inhibition (Chapter 140).
5. Golgi cell that is activated by mossy fibers, in turn, provides feedback inhibition to granule cells by releasing **GABA,** i.e. it inhibits the transmission of impulse from mossy fiber to granule cell
6. Cerebellar nuclei are excited by collaterals from climbing and mossy fibers. In turn, the nuclei send excitatory impulses to thalamus and different nuclei in brainstem.
7. However, signals discharged from Purkinje cells inhibit cerebellar nuclei via GABA. Purkinje cells

TABLE 150.2: Interneuronal activity in cerebellum

Neuron	Action on	Action	Neurotransmitter
Climbing fibers	Purkinje cells and Cerebellar nuclei	Excitation	Aspartate
Mossy fibers	Granule cells Golgi cells and Cerebellar nuclei	Excitation	Glutamate
Granule cells	Purkinje cells Stellate cells Basket cells	Excitation	Glutamate/Aspartate
Stellate cells	Purkinje cells	Inhibition	GABA
Basket cells	Purkinje cells	Inhibition	GABA
Golgi cells	Granule cells	Inhibition	GABA
Purkinje cells	Cerebellar nuclei Vestibular nuclei	Inhibition	GABA

GABA = Gamma aminobutyric acid

inhibit the activities of vestibular nuclei also. Thus, it is clear that the cerebellar cortex plays an important role in modulating the excitatory signals of following pathways:

i. From cerebellar nuclei to cerebral cortex via thalamus
ii. From final common motor pathway via brainstem and spinal cord.

Because of this activity of cerebellar cortex, movements of body are well organized and coordinated.

CEREBELLAR NUCLEI

Cerebellar nuclei are the masses of gray matter scattered in the white matter of cerebellum. There are four nuclei on either side (Fig. 150.3).

1. *Fastigial Nucleus*

Fastigial nucleus is also known as **nucleus fastigi.** Phylogenetically, it is the oldest cerebellar nucleus. It is placed near the midline on the roof of IV ventricle.

2. *Globosus Nucleus*

Globosus nucleus is situated lateral to nucleus fastigi. This is also known as **nucleus globosus.**

3. *Emboliform Nucleus*

Emboliform nucleus is also called **nucleus emboliformis.** This nucleus is below the nucleus fastigi and nucleus globosus.

4. *Dentate Nucleus*

Dentate nucleus is also called **nucleus dentatus.** It is the largest cerebellar nucleus. As it is crenated, it is called dentate nucleus. It is situated lateral to all the other nuclei.

WHITE MATTER OF CEREBELLUM

White matter of cerebellum is formed by afferent and efferent nerve fibers. These nerve fibers are classified into three groups.

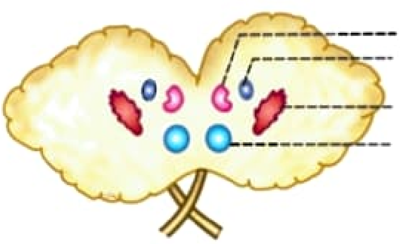

FIGURE 150.3: Cerebellar nuclei

1. *Association fibers*

Association fibers connect different regions of same cerebellar hemisphere.

2. *Commissural fibers*

Commissural fibers connect the areas of both halves of cerebellar cortex.

3. *Projection fibers*

Projection fibers are the afferent and efferent nerve fibers which connect cerebellum with other parts of central nervous system. Projection fibers of cerebellum are arranged in three bundles (Fig. 150.4):

i. Inferior cerebellar peduncles between cerebellum and medulla oblongata
ii. Middle cerebellar peduncles between cerebellum and pons
iii. Superior cerebellar peduncles between cerebellum and midbrain.

i. *Inferior Peduncles*

Inferior cerebellar peduncles are otherwise called **restiform bodies** and contain predominantly afferent fibers. These nerve fibers transmit the impulses from tactile receptors, proprioceptors and receptors in vestibular apparatus to cerebellum.

ii. *Middle Peduncles*

Middle cerebellar peduncles are otherwise called **brachia pontis.** These penduncles contain predominantly, the afferent fibers. Most of the fibers of the middle cerebellar peduncles are commissural fibers, which connect the areas of both the halves of cerebellar cortex.

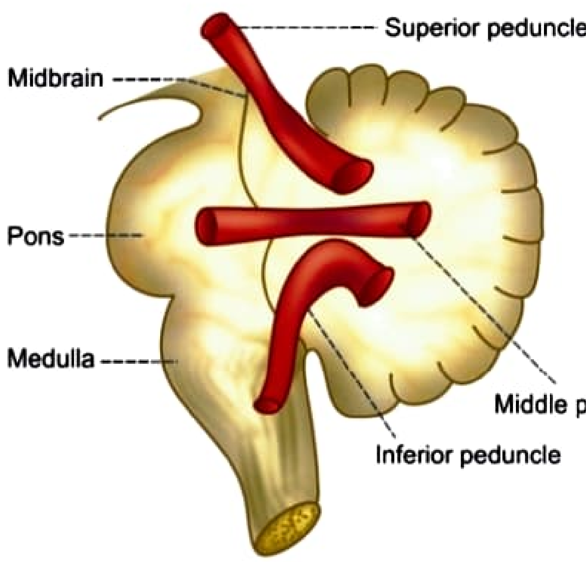

FIGURE 150.4: Cerebellar peduncles

iii. *Superior Peduncles*

Superior cerebellar peduncles are otherwise called the **brachia conjunctivae** and contain predominantly, efferent fibers.

VESTIBULOCEREBELLUM (ARCHICEREBELLUM)

Vestibulocerebellum is connected with the **vestibular apparatus** and so it is known as vestibulocerebellum. Since vestibulocerebellum is the phylogenetically oldest part of cerebellum, it is also called **archicerebellum.** It is concerned with the maintenance of posture and equilibrium.

COMPONENTS

Vestibulocerebellum includes the **flocculonodular lobe** that is formed by the **nodulus** of vermis and its lateral extensions called **flocculi** (Fig. 150.1 and Table 150.3).

Uvula of vermis is also considered as the part of vestibulocerebellum by some physiologists.

CONNECTIONS

Afferent Connections

Vestibulocerebellar tract

Vestibulocerebellar tract is formed by the fibers arising from the vestibular nuclei, situated in pons and medulla. It passes through the inferior cerebellar peduncle of the same side and reaches the cerebellar nuclei, nucleus globosus, nucleus emboliformis and nucleus fastigi (Fig. 150.5). Fibers from these nuclei, reach the vestibulocerebellum (flocculonodular node).

Vestibular nuclei in turn, receive fibers from vestibular apparatus situated in the inner ear, through vestibular division of cochlear (VIII cranial) nerve.

Efferent Connections

1. *Cerebellovestibular tract*

Fibers of cerebellovestibular tract arise from the flocculonodular lobe, pass through the inferior cerebellar peduncle of the same side and terminate on the vestibular nuclei in brainstem.

Fibers from vestibular nuclei form medial and lateral vestibulospinal tracts, which terminate on the medial group of alpha motor neurons in the spinal cord. This pathway forms the part of medial system of motor pathway (extrapyramidal system).

2. *Fastigiobulbar tract*

Fibers of fastigiobulbar tract arise from fastigial nucleus, pass through inferior cerebellar peduncle of the same side and terminate on vestibular nuclei and reticular formation in medulla oblongata.

From vestibular nuclei, vestibulospinal tracts (mentioned above) arise and terminate on alpha motor neurons. From reticular formation, reticulospinal tract arises and terminates on gamma motor neurons in the spinal cord forming the part of medial motor system (extrapyramidal system).

TABLE 150.3: Components and connections of functional divisions of cerebellum

Division	Components	Afferent connections	Efferent connections
Vestibulocerebellum	Flocculonodular lobe (nodulus and flocculi)	Vestibulocerebellar tract	1. Cerebellovestibular tract 2. Fastigiobulbar tract
Spinocerebellum	Lingula Central lobe Culmen Lobulus simplex Declive Tuber Pyramid Uvula Paraflocculi and Medial portions of cerebral hemispheres	1. Dorsal spinocerebellar tract 2. Ventral spinocerebellar tract 3. Cuneocerebellar tract 4. Olivocerebellar tract 5. Pontocerebellar tract 6. Tectocerebellar tract 7. Trigeminocerebellar tract	1. Fastigiobulbar tract 2. Cerebelloreticular tract 3. Cerebello-olivary tract
Corticocerebellum	Lateral portions of cerebral hemispheres	1. Pontocerebellar tract 2. Olivocerebellar tract	1. Dentatothalamic tract 2. Dentatorubral tract

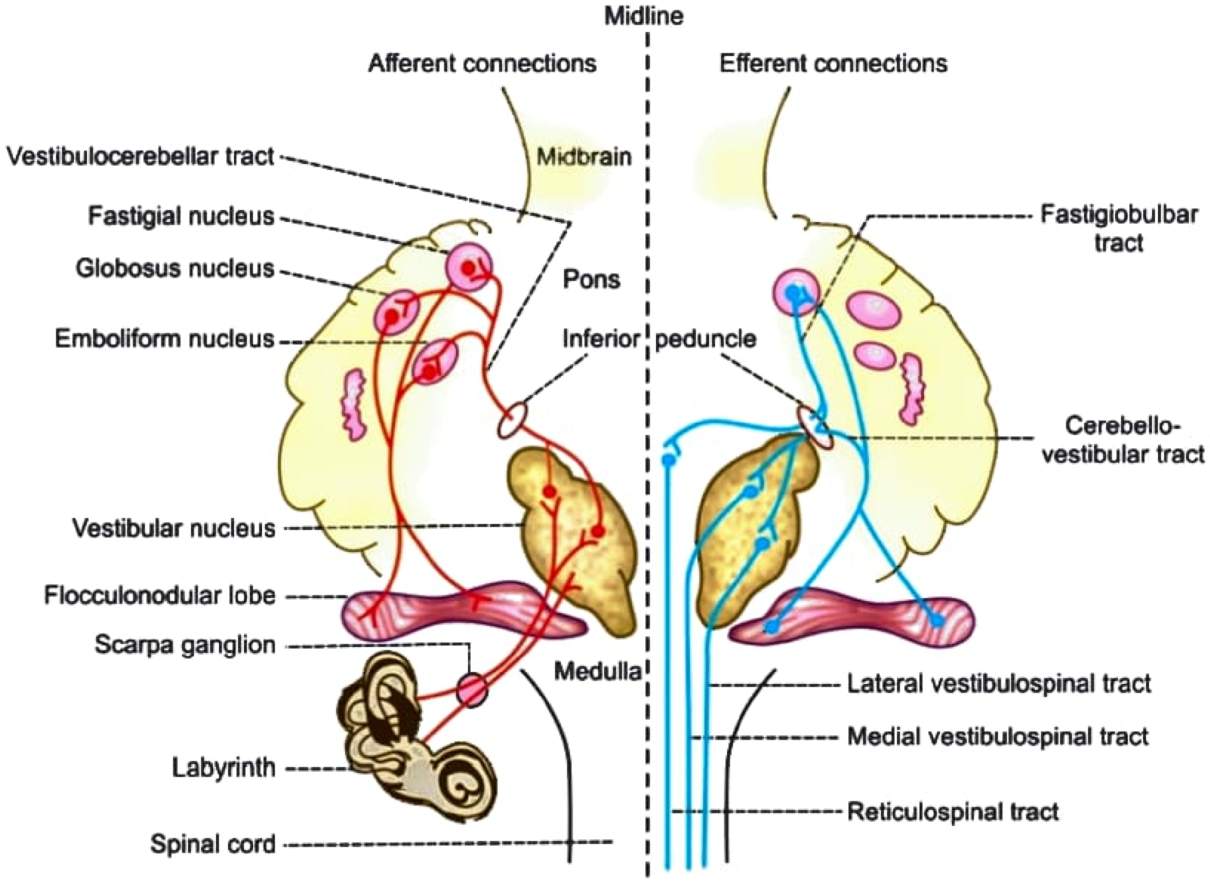

FIGURE 150.5: Connections of vestibulocerebellum. Red = Affernt connections, Blue = Efferent connections.

FUNCTIONS

Vestibulocerebellum regulates **tone, posture** and **equilibrium** by receiving impulses from vestibular apparatus. Vestibular apparatus sends information regarding gravity, linear movement and angular acceleration to vestibulocerebellum through vestibulocerebellar tract. Vestibulocerebellum, in turn, sends signals to spinal cord via vestibulospinal and reticulospinal tracts.

Mechanism of Action of Vestibulocerebellum

Normally, vestibular nuclei **facilitate the movements** of trunk, neck and limbs through vestibulospinal tracts and alpha motor neurons. Medullary reticular formation **inhibits the muscle tone** through reticulospinal tract and gamma motor neurons.

However, vestibulocerebellum inhibits both vestibular nuclei and medullary reticular formation. As a result, the **movements** of neck, trunk and limbs are **checked** and the **muscle tone increases.** Because of these effects, any disturbance in posture and equilibrium is corrected.

In the lesion of vestibulocerebellum, there is a reduction in muscle tone (hypotonia) and failure to maintain posture and equilibrium.

SPINOCEREBELLUM (PALEOCEREBELLUM)

Spinocerebellum is connected with spinal cord and hence the name. It forms the major **receiving area** of cerebellum for sensory inputs. It is concerned with the maintenance of muscle tone and anticipatory adjustment of muscle contraction during movement. Spinocerebellum is also phylogenetically older part of cerebellum. It is otherwise called **paleocerebellum.**

COMPONENTS

Spinocerebellum consists of medial portions of **cerebellar hemisphere,** paraflocculi and the parts of vermis, viz. lingula, central lobe, culmen, lobulus simplex, declive, tuber, pyramid and uvula (Fig. 150.1 and Table 150.3). However, some physiologists do not consider uvula as a part of spinocerebellum.

■ CONNECTIONS

Afferent Connections

1. *Dorsal spinocerebellar tract*

Dorsal spinocerebellar tract arises from Clarke's column of cells in the dorsal gray horn of spinal cord. It is uncrossed tract and reaches the spinocerebellum through the inferior peduncle of same side (Fig. 150.6). This tract conveys the proprioceptive information from the limbs of same side regarding the position and movements.

2. *Ventral spinocerebellar tract*

Fibers of ventral spinocerebellar tract arise from the marginal cells in the dorsal gray horn of spinal cord. After taking the origin, the fibers cross the midline, ascend in the opposite side and reach the spinocerebellum through superior cerebellar peduncle. This tract conveys the information about the position and movements of opposite limbs to spinocerebellum.

3. *Cuneocerebellar tract*

Cuneocerebellar tract arises from accessory cuneate nucleus, situated lateral to cuneate nucleus in medulla. It reaches the spinocerebellum through the inferior cerebellar peduncle of the same side. This tract conveys the proprioceptive impulses from upper limb, upper trunk and neck to spinocerebellum.

4. *Olivocerebellar tract*

Olivocerebellar tract is formed by climbing fibers arising from the inferior olivary nucleus in medulla. After taking origin, these fibers cross the midline and reach

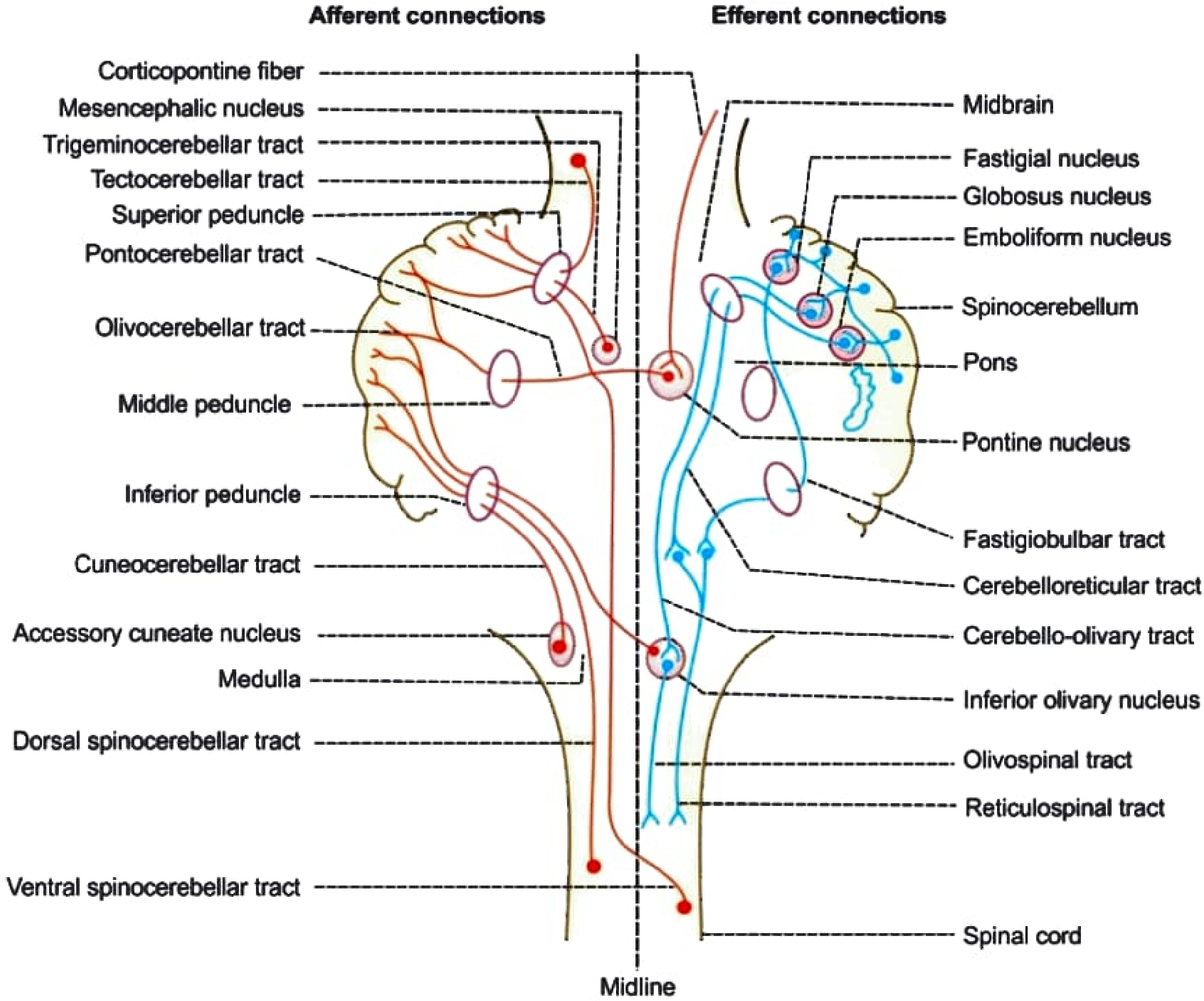

FIGURE 150.6: Connections of spinocerebellum. Red = Afferent connections, Blue = Efferent connections.

the spinocerebellum through the inferior cerebellar peduncle of the opposite side. This tract also gives collaterals to cerebellar nuclei, particularly the globosus nucleus and emboliform nucleus. Inferior olivary nucleus receives afferent fibers from three sources:

i. Brainstem nuclei of same side
ii. Spinal cord through spino-olivary tract of same side
iii. Cerebral cortex of opposite side.

Olivocerebellar tract conveys proprioceptive impulses from the body and output signals from cerebral cortex to spinocerebellum.

5. *Pontocerebellar tract*

Pontocerebellar tract arises from pontine nuclei, crosses the midline and reaches the spinocerebellum through the middle cerebellar peduncle of opposite side. Pontine nuclei receive afferents from cerebral cortex. Pontocerebellar tract conveys the information to spinocerebellum about the motor signals discharged from cerebral cortex.

6. *Tectocerebellar tract*

Tectocerebellar tract arises from superior and inferior colliculi of tectum in midbrain. It reaches the spinocerebellum through superior cerebellar peduncle of the same side. This tract carries visual impulses from superior colliculus and auditory impulses from inferior colliculus to spinocerebellum.

7. *Trigeminocerebellar tract*

Trigeminocerebellar tract is formed by the fibers arising from mesencephalic nucleus of trigeminal nerve. It reaches the spinocerebellum via superior cerebellar peduncle of same side. This tract conveys proprioceptive information from jaw muscles and temporomandibular joint to spinocerebellum. It also carries the sensory impulses from the periodontal tissues (tissues around the teeth) to spinocerebellum.

Efferent Connections

Cortex of spinocerebellum is projected into the nuclei fastigi, emboliformis and globosus of cerebellum. Fibers from these nuclei pass through following tracts:

1. *Fastigiobulbar tract*

Fastigiobulbar tract arises from fastigial nucleus, passes through superior cerebellar peduncle of same side and ends in the reticular formation.

2. *Cerebelloreticular tract*

Fibers of cerebelloreticular tract arise from the emboliform and globosus nuclei, pass through superior cerebellar peduncle of same side and terminate in the reticular formation.

From reticular formation, reticulospinal tract arise and terminate on the gamma motor neurons of spinal cord.

3. *Cerebello-olivary tract*

Cerebello-olivary tract arises from the emboliform and globosus nuclei and reaches the inferior olivary nucleus of the same side by passing through the superior cerebellar peduncle. From olivary nucleus, the olivospinal tract arises and fibers of this tract end on the alpha motor neurons of spinal cord.

FUNCTIONS

Spinocerebellum regulates **tone, posture** and **equilibrium** by receiving sensory impulses form tactile receptors, proprioceptors, visual receptors and auditory receptors.

Spinocerebellum is the **receiving area** for tactile, proprioceptive, auditory and visual impulses. It also receives the cortical impulses via pontine nuclei. Tactile and proprioceptive impulses are localized in the spinocerebellum. **Localization** of tactile and proprioceptive impulses in spinocerebellum is determined by stimulating the tactile receptors and the proprioceptors and by recording the electrical responses in different parts of spinocerebellum. The different parts of the body are represented in the spinocerebellum in the following manner:

Lingula	:	Coccygeal region
Central lobe	:	Hind limb
Culmen	:	Forelimb
Lobulus simplex	:	Face and head.

In cerebral cortex, different parts of the body are represented in an inverted manner. But in cerebellum, different parts are represented in upright manner.

Spinocerebellum regulates the postural reflexes by modifying muscle tone. It facilitates the discharge from gamma motor neurons in spinal cord via cerebello-vestibulospinal and cerebello-reticulospinal fibers. Increased discharge from gamma motor neurons **increases the muscle tone.** Lesion, destruction or abolishing the function of spinocerebellum by cooling, causes stoppage of discharge from gamma motor neurons, resulting in hypotonia and disturbances in posture.

Spinocerebellum also receives impulses from optic and auditory pathway and helps in adjustment of posture and equilibrium in response to visual and auditory impulses.

CORTICOCEREBELLUM (NEOCEREBELLUM)

Corticocerebellum is the largest part of cerebellum. Because of its connection with cerebral cortex, it is called corticocerebellum or **cerebrocerebellum.** It is phylogenetically newer part of cerebellum. So, it is also called **neocerebellum.** It is concerned with planning, programming and coordination of skilled movements.

■ COMPONENTS

Corticocerebellum includes the lateral portions of cerebellar hemispheres (Fig. 150.1 and Table 150.3).

■ CONNECTIONS

Afferent Connections

1. *Pontocerebellar tract*

Pontocerebellar tract arises from pontine nuclei, crosses the midline and enters corticocerebellum via middle cerebellar peduncle (Fig. 150.7). It is the largest tract in the body having about 20 million nerve fibers.

Pontocerebellar tract is also called the corticopontocerebellar circuit. Because, it receives signals from motor area of cerebral cortex and conveys those signals to corticocerebellum. It helps the cerebellum in planning the movements initiated by the cerebral cortex.

2. *Olivocerebellar tract*

Olivocerebellar tract arises from the inferior olivary nucleus situated in medulla. It crosses the midline and enters corticocerebellum via inferior cerebellar peduncle of the opposite side. There it terminates on the dentate nucleus and cerebellar cortex. This tract is formed by climbing fibers.

Inferior olivary nucleus receives impulses from brainstem, spinal cord and cerebral cortex and conveys these impulses to the corticocerebellum through the olivocerebellar tract.

Efferent Connections

Output signals from corticocerebellum are relayed mainly through the dentate nucleus. Fibers from dentate nucleus pass through superior cerebellar peduncle, cross the midline and form decussation with the fibers of opposite side. After forming the decussation, these fibers divide into two tracts:

1. Dentatothalamic tract
2. Dentatorubral tract.

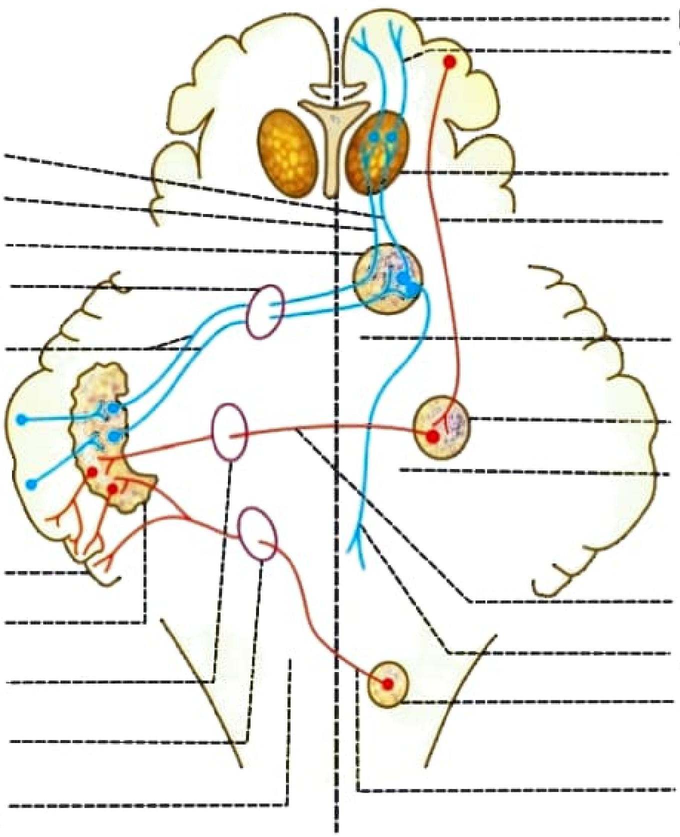

FIGURE 150.7: Connections of corticocerebellum. Red = Afferent connections, Blue = Efferent connections.

1. *Dentatothalamic tract*

After crossing, some of the fibers pass through red nucleus without having any synapse and terminate in lateral ventral nucleus of thalamus. Tract formed by these fibers is called dentatothalamic tract. Thalamus in turn, projects into the motor area of cerebral cortex via thalamocortical fibers.

2. *Dentatorubral tract*

Remaining fibers terminate in the red nucleus of opposite side as dentatorubral tract. Three tracts arise from red nucleus:

i. Rubrothalamic tract: From red nucleus, this tract ascends and terminates in lateral ventral nucleus of thalamus. From here, thalamocortical fibers arise and reach the cerebral cortex.
ii. Rubroreticular tract: It descends down and ends in reticular formation. Reticular formation projects into spinal cord via reticulospinal tract.
iii. Rubrospinal tract: Red nucleus also projects directly into spinal cord through rubrospinal tract.

■ AFFERENT-EFFERENT CIRCUIT (CEREBRO-CEREBELLO-CEREBRAL CONNECTIONS)

Afferent-efferent circuit is an important neuronal pathway, involved in cerebellar control of voluntary movements, initiated by the motor area of cerebral cortex. This pathway includes two tracts:

1. Cerebropontocerebellar tract
2. Dentatorubrothalamocortical tract.

1. Cerebropontocerebellar Tract

Fibers from motor areas 4 and 6 in frontal lobe of cerebral cortex enter the pontine nuclei. These fibers are called corticopontine fibers (Figs. 150.8 and 150.9). From pontine nuclei, the pontocerebellar fibers arise and pass through middle cerebellar peduncle of the opposite side and terminate in the cerebellar cortex. This pathway is called the cerebropontocerebellar tract.

2. Dentatorubrothalamocortical Tract

Cerebellar cortex is, in turn, connected to the dentate nucleus. Fibers from the dentate nucleus pass via superior cerebellar peduncle and end in red nucleus of opposite side. These fibers are called dentatorubral fibers. From red nucleus, the rubrothalamic fibers go to thalamus. Thalamus is connected to areas 4 and 6 in motor cortex of cerebrum by thalamocortical fibers. This pathway is called dentatorubrothalamocortical tract.

■ FUNCTIONS

Corticocerebellum is concerned with the **integration** and **regulation** of well-coordinated **muscular activities.** It is because of its afferent-efferent connection with cerebral cortex through the cerebro-cerebello-cerebral circuit (Table 150.4). Apart from its connections with cerebral cortex, cerebellum also receives feedback signals from the muscles through the nerve fibers of proprioceptors.

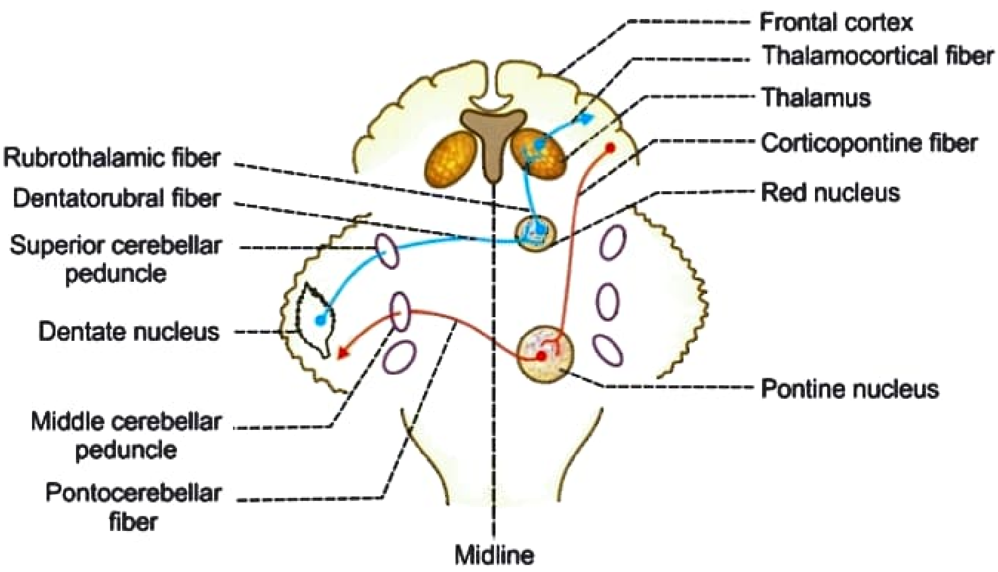

FIGURE 150.8: Cerebro-cerebello-cerebral circuit

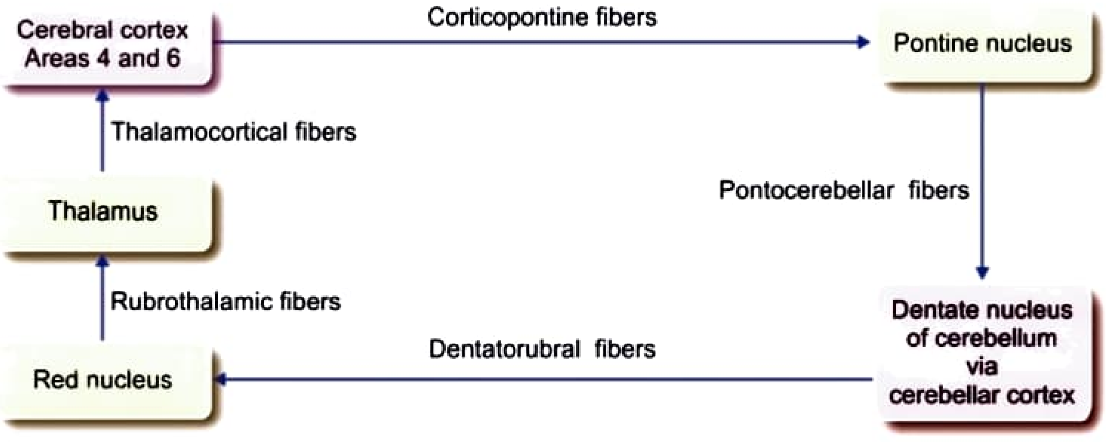

FIGURE 150.9: Schematic representation of cerebro-cerebello-cerebral circuit

TABLE 150.4: Functions of cerebellum

Functions		Division of cerebellum involved
1. Regulation of tone, posture and equilibrium	By receiving impulses from vestibular apparatus	Vestibulocerebellum
	By receiving impulses from proprioceptors in muscles, tendons and joints, tactile receptors, visual receptors and auditory receptors	Spinocerebellum
2. Regulation of coordinated movements	i. Damping action ii. Control of ballistic movements iii. Timing and programming the movements iv. Servomechanism v. Comparator function	Corticocerebellum (Neocerebellum)

Mechanism of Action of Corticocerebellum

1. *Damping action*

Damping action refers to prevention of exaggerated muscular activity. This helps in making the voluntary movements smooth and accurate. All the voluntary muscular activities are initiated by motor areas of cerebral cortex. Simultaneously, corticocerebellum receives impulses from motor cortex as well as feedback signals from the muscles, as soon as the muscular activity starts.

Corticocerebellum, in turn, sends information (impulses) to cerebral cortex to discharge only appropriate signals to the muscles and to cut off any extra impulses. Because of this damping action of corticocerebellum, the exaggeration of muscular activity is prevented and the movements become smooth and accurate. Literally, the word damping means any effect that decreases the amplitude of mechanical oscillation.

2. *Control of ballistic movements*

Ballistic movements are the rapid alternate movements, which take place in different parts of the body while doing any skilled or trained work like typing, cycling, dancing, etc. Corticocerebellum plays an important role in preplanning the ballistic movements during learning process.

3. *Timing and programming the movements*

Corticocerebellum plays an important role in timing and programming the movements, particularly during learning process. While using a typewriter or while doing any other fast-skilled work, a chain of movements occur rapidly in a sequential manner. During the learning process of these skilled works, corticocerebellum plans the various sequential movements. It also plans schedule of time duration of each movement and the time interval between movements. All the information from corticocerebellum are communicated to **sensory motor area** of cerebral cortex and stored in the form of memory. So, after the learning process is over, these activities are executed easily and smoothly in a sequential manner.

4. Servomechanism

Servomechanism is the correction of any disturbance or interference while performing skilled work. Once the skilled works are learnt, the sequential movements are executed without any interruption. Cerebellum lets the cerebral cortex to discharge the signals, which are already programed and stored at sensory motor cortex and does not interfere much. However, if there is any disturbance or interference, the corticocerebellum immediately influences the cortex and corrects the movements.

5. *Comparator function*

Comparator function of the corticocerebellum is responsible for the integration and coordination of the various muscular activities.

On one side, cerebellum receives the information from cerebral cortex, regarding the cortical impulses which are sent to the muscles. On the other side, it receives the feedback information (proprioceptive impulses) from muscles, regarding their actions under the instruction of cerebral cortex.

By receiving the messages from both ends, corticocerebellum compares the cortical commands for muscular activity and the actual movements carried out by the muscles. If any correction is to be done, then, corticocerebellum sends instructions (impulses) to the motor cortex.

Accordingly, cerebral cortex corrects or modifies the signals to muscles, so that the movements become accurate, precise and smooth. This function of corticocerebellum is known as comparator function.

Simultaneously, it also receives impulses from tactile receptors, eye and ear. Such additional information facilitates the comparator function of corticocerebellum.

■ APPLIED PHYSIOLOGY – CEREBELLAR LESIONS

Cerebellar lesions may be due to tumor, abscess or an injury. Excess alcohol ingestion also leads to cerebellar lesions. Loss of functions of cerebellum also occurs due to degenerative changes in cerebellar cortex, cerebellar nuclei, cerebellar peduncles and spinocerebellar tracts.

In general, during cerebellar lesions, there are disturbances in posture, equilibrium and movements. In unilateral lesion, symptoms appear on the affected side because cerebellum controls the same **(ipsilateral)** side of the body.

Most of the disturbances are due to the damage to corticocerebellum (neocerebellum) because in human beings, it is larger than other divisions.

■ DISTURBANCES IN TONE AND POSTURE

1. *Atonia or Hypotonia*

Atonia is the loss of tone and hypotonia is reduction in tone of the muscle. Cerebellar lesion causes atonia or hypotonia, depending upon the severity of the lesion. Atonia or hypotonia due to cerebellar lesion causes disturbances in the postural reflexes.

Cause for atonia or hypotonia during cerebellar lesion is the loss of facilitatory impulses to gamma motor neurons in the spinal cord via cerebello-vestibulospinal and cerebello-reticulospinal fibers.

2. *Attitude*

Attitude of the body changes in unilateral lesion of the cerebellum. Changes in the attitude are:

i. Rotation of head towards the opposite side (unaffected side)
ii. Lowering of shoulder on the same side
iii. Abduction of leg on the affected side. Leg is rotated outward.
iv. Weight of the body is thrown on leg of unaffected side. So, trunk is bent with concavity towards the affected side.

3. *Deviation Movement*

Deviation movement is the lateral deviation of arms when both the arms are stretched and held in front of the body, with closed eyes. In bilateral lesion, both the arms deviate and in unilateral lesion, arm of the affected side deviates.

4. *Effect on Deep Reflexes*

Pendular movements (Chapter 142) occur while eliciting a tendon jerk. These movements are very common while eliciting the knee jerk or patellar tendon reflex in the patients affected by cerebellar lesion.

A tap on the patellar tendon when leg is hanging freely causes a brisk extension of leg due to the contraction of quadriceps muscle. In normal conditions, after extension, the leg returns back to resting position immediately. In cerebellar lesion, the leg shows pendular movements.

■ DISTURBANCES IN EQUILIBRIUM

While Standing

While standing, the legs are spread to provide a broad base and the body sways side-to-side with oscillations of the head.

While Moving – Gait

Gait means manner of walking. In cerebellar lesion, a staggering, reeling and **drunken-like gait** is observed.

■ DISTURBANCES IN MOVEMENTS

1. *Ataxia:* Lack of coordination of movements.
2. *Asynergia:* Lack of coordination between different groups of muscles such as protagonists, antagonists and synergists.
3. *Asthenia:* Weakness, easy fatigability and slowness of muscles.
4. *Dysmetria:* Inability to check exact strength and duration of muscular contractions required for any voluntary act. While reaching for an object, the arm may overshoot (past pointing) or it may fall short of the object. Overshooting is called **hypermetria** and falling short is known as **hypometria.**
5. *Intention tremor:* Tremor that occurs while attempting to do any voluntary act. Refer Chapter 147 for details of tremor.
6. *Astasia:* Unsteady voluntary movements.
7. *Nystagmus:* To and fro movement of eyeball is called nystagmus. Details of nystagmus are given in Chapter 158.
8. *Rebound phenomenon:* When the patient attempts to do a movement against resistance and if the resistance is suddenly removed, the limb moves forcibly in the direction in which the attempt was made. It is called rebound phenomenon. It is due to the absence of breaking action of antagonistic muscle.
9. *Dysarthria:* Disturbance in speech. It is due to the incoordination of various muscles and structures involved in speech.
10. *Adiadochokinesis:* Ability to do rapid alternate successive movements such as supination and pronation of arm is called **diadochokinesis.** Inability to do rapid alternate successive movements is called adiadochokinesis. It is a common feature of cerebellar lesion. It is also called **dysdiadochokinesia.**